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THE MUDDY MOUNTAIN OVERTHRUST IN SOUTHEASTERN NEVADA¹

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INTRODUCTION

Geologists have long recognized the fact that the region of the Basin Ranges has passed through more than one period of deformation since the middle of the Mesozoic era. The most recent important disturbance found expression chiefly in great normal faults, which divided the crust into essentially parallel mountain ranges. Within many of these mountain blocks the structure is complex. Tertiary formations are strikingly unconformable among themselves, and rest with profound unconformity on the older rocks. This great unconformity is a record of prolonged erosion following an epoch of crustal compression in Mesozoic time. The youngest rocks involved in this disturbance appear to be of Jurassic age; and therefore it is probable that the movement was contemporaneous with the folding of the Sierra Nevada and Humboldt Ranges.

The degree of deformation due to this mountain-making varies greatly in the different ranges. In some the Mesozoic and older strata appear to have been nearly horizontal before the last important period of faulting. Other ranges preserve a record of the Nevadian movement in folds of varying intensity. In the Muddy Mountains of southeastern Nevada the record consists of overturned folds and an overthrust of considerable magnitude. These structural features were recognized by the writer in the course of field work during the summer of 1919, and a brief description has appeared in another article.² The present paper will give a more detailed description of the overthrust (Figs. 1 and 2).

¹ Published by permission of the Director of the United States Geological Survey.

² *Amer. Jour. of Sci.*, Vol. L (Jan., 1921), pp. 39-62.

TOPOGRAPHY OF THE MUDDY MOUNTAINS

The Muddy Mountains are a complex range bounded by wide valleys of structural origin. From north to south the length of the range is nearly 40 miles, and the maximum width, measured from

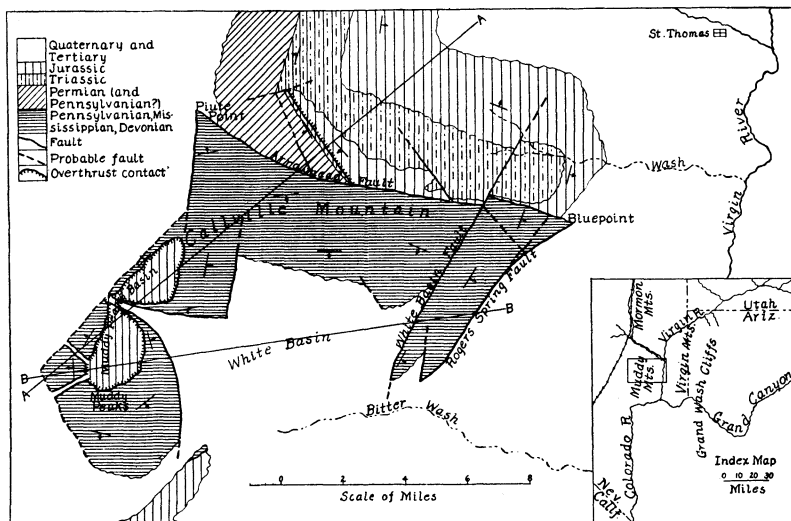


FIG. 1.—Generalized geologic map showing the Muddy Mountain overthrust

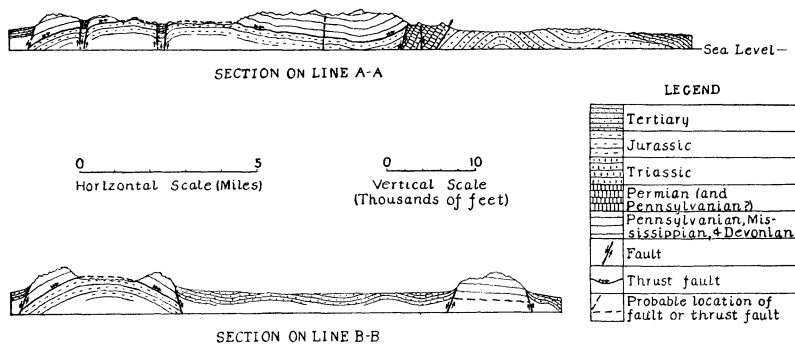


FIG. 2.—Cross sections showing structure in the Muddy Mountains

east to west, is approximately 15 miles. The intermontane valleys form a border several miles in width, with elevations ranging from less than 1000 to slightly over 2,000 feet above sea-level. The northern part of the mountains consists of ridges developed by

differential erosion on tilted strata. These ridges trend generally north and south and are elevated only a few hundred feet above the bordering valleys. Similar ridges, trending northeastward, form the southern part of the mountains. The central division consists of faulted portions of an overthrust block, and is the dominating part of the range. This division of the mountains is shaped roughly like a letter C, with the opening toward the south. It is a distinct unit, made conspicuous by its superior average elevation, by the abrupt faces bounding it on practically all sides, and by the dark Paleozoic limestones that form the greater part of the mass. For convenience in reference the unit has been called Callville Moun-



FIG. 3.—View of White Basin and part of Callville Mountain, looking northwest from the south end of the White Basin fault scarp.

tain. Its upper surface is rugged, and a number of sharp peaks rise prominently above the general elevation. Muddy Peaks, the highest points, are nearly 5,800 feet above sea-level. Immediately north of the peaks the continuity of the mountain has been somewhat broken by faulting and erosion, and Jurassic sandstone is exposed in a depression known as Muddy Peaks Basin. White Basin, a low area floored by light-colored Tertiary deposits, lies within the curve of the C formed by Callville Mountain (Fig. 3).

STRATIGRAPHY

Except for small amounts of igneous materials, all of the rocks exposed in the Muddy Mountains are sedimentary. They include strata of Paleozoic, Mesozoic, and Cenozoic age. The Callville Mountain block consists of four formations, chiefly heavy limestones.

recognized as Devonian, Mississippian, and Pennsylvanian. The lowest horizon at which fossils were found lies nearly 1,000 feet above the base of the series, and therefore a part of the lower beds may belong to periods older than the Devonian. At the top of the block an unknown thickness of the Pennsylvanian beds has been removed by erosion. Outside the borders of Callville Mountain the oldest strata exposed are the upper part of the Supai formation, which is mapped (Fig. 1) with the Permian. Thus there is a gap of undetermined value in the stratigraphic succession. The following table summarizes the nature of formations and shows their relationships:

Age		Formation	Nature	Thickness (in feet)
Quaternary		Alluvial deposits	Gravel, sand, and silt	0-400
Tertiary	P. iocene ?	-Unconformity Intermontane clays	Clay, silt, and sand, with salt, gypsum, and other saline deposits	200-1800
	Miocene ?	-Unconformity Horse Spring formation	Limestone, clay, sandstone, conglomerate, volcanic ash, magnesium carbonate, gypsum, and other saline materials	1000-2800
		Overton fanglomerate	Coarse alluvial fan deposits, in part firmly cemented	
		-Great unconformity Cross-bedded sandstone (equivalent to the LaPlata group)	Red and gray sandstone, with extreme cross-bedding	750-2000
Jurassic				
Triassic		Chinle formation	Sandstone, shale, and gypsum, with some silicified wood	800-3200
		Shinarump conglomerate	Conglomerate and cross-bedded sandstone, with abundance of silicified wood	10-200
		-Disconformity Moenkopi formation	Limestone, shale, sandstone, and gypsum	1200-1600
		-Disconformity Kaibab limestone	Heavy beds of limestone, with some sandstone and gypsum	400-700
Permian				
Pennsylvanian ?		Supai formation	Red and gray sandstone, in part cross-bedded, with some gypsum and gypsiferous shale	100-800 (incomplete exposures)
Pennsylvanian		Unknown thickness not exposed Callville limestone	Heavy beds of dark gray limestone, cherty in part	1100 (incomplete)
Mississippian		Bluepoint limestone	Dark carbonaceous limestone, with chert nodules	900
		Rogers Spring formation	Cherty limestone and dark gray quartzite	600
Devonian (and older?)		-Disconformity Muddy Peaks limestone	Heavy beds of gray limestone, in part carbonaceous	1200

STRUCTURE OF CALLVILLE MOUNTAIN

Fault boundaries.—Very evidently the steep sides of Callville Mountain are in large part due to normal faulting. Portions of the actual fault surface are well exposed, and at many points the adjacent younger formations may be seen in fault contact with the Paleozoic rocks of the mountain. The White Basin fault scarp is exceptionally well preserved. Adjacent to White Basin it is several hundred feet high, and its remarkable regularity gives it the appearance of an artificial wall. At the base of the scarp, Tertiary beds are turned steeply upward along the edge of the down-thrown block, and large slickensided surfaces are numerous on the hard Paleozoic limestone of the footwall. Slickensides are distinguishable even at a height of more than 100 feet above the base of the cliff. These fault surfaces have an average westward inclination of 50° , and near its southern end the scarp as a whole has the same inclination to a height of nearly 1,000 feet. The undissected character of the scarp is due in part to the eastward tilt of the footwall block. Consequent streams on the block flow eastward, and have cut deep canyons across the Rogers Spring fault scarp, which accordingly has a much older appearance than the White Basin scarp. At the base of the Rogers Spring front the Tertiary beds are upturned steeply toward the mountain, and portions of the fault plane are exposed, dipping 60° eastward. The block east of the fault has been thrown at least several hundred feet. Thus the part of Callville Mountain included between the Rogers Spring and White Basin faults is a typical horst.

Similar faults, all with large throw, bound White Basin on the west, and at least a part of the west boundary of Callville Mountain is formed by normal fault scarps. It is very natural, therefore, to infer that the mountain is an irregular horst or group of horsts left elevated by the sinking of adjacent blocks. For the northern boundary, however, this explanation is not tenable. This side of the mountain is high and precipitous, and has the general appearance of an eroded fault scarp; but the fault plane, exposed at many points near the base of the cliff, has an average dip of nearly 70° to the south, and the older strata of the mountain have very evidently moved down with respect to the younger formations on the north.

Therefore the original topographic expression of the fault has been reversed by differential erosion. This anomalous relation indicates that the structure is more complex than is apparent at the borders of the mountain (Fig. 4).

Overthrust relations.—The key to the older structure of Callville Mountain is furnished by Muddy Peaks Basin. Pronounced doming has affected the western part of the mountain, the strata on the sides of the dome dipping at a maximum of 45° . Erosion has stripped the thick Paleozoic beds from the



FIG. 4.—Portion of the north front of Callville Mountain. In the foreground, Triassic sediments are masked by recent waste. Outcrops of Jurassic sandstone partly covered by talus near base of cliff.

summit of the dome, exposing cross-bedded Jurassic sandstone beneath. The sandstone forms the floor of an erosional basin, which has been divided into two lobes by a faulted tongue of Tertiary sediments. Limestone walls rise abruptly around the margins of the basin, and are retreating rapidly due to sapping of the comparatively weak sandstone beneath. Remnants of the limestone, lying almost horizontally, cap sandstone hills near the center of the basin. The contact of limestone and sandstone, well exposed at many places, is plainly one of overthrust, and is essentially parallel to the bedding both below and above. Immediately above the thrust surface a breccia has been developed, the thickness ranging from a few feet to at least 75 feet. Most of the fragments are of limestone, but near the base some pieces of sand-

stone are included. The breccia is well cemented with calcium carbonate, and the base is smoothly polished. Above the zone of typical breccia the limestone is intensely shattered through a thickness ranging from 100 to 500 feet. The shattered condition of the rock is responsible for the development of numerous grotesque forms by the agents of erosion.

There can be no reasonable doubt that the formation beneath the overthrust is the Jurassic sandstone, corresponding to the LaPlata group. No fossils have been found in this formation, but its lithologic features are very distinctive. The only other formation in the region that in any way resembles it is the Supai;



FIG. 5.—View to the northwest across Muddy Peaks Basin, showing remnants of dark Paleozoic limestone capping hills of Jurassic sandstone.

and to anyone who has studied the two formations carefully the differences are sufficiently apparent to prevent confusion. A thickness of approximately 700 feet of the sandstone is exposed in Muddy Peaks Basin, and throughout this thickness the rock has large scale cross-bedding, both straight and tangential; it has alternating laminae with coarse and fine grains; and it shows an irregular blending of red coloring with gray. All of these features are typical of the Jurassic sandstone.

Extent of the overthrust.—It is quite certain that the entire Callville Mountain mass is included in the overthrust block, although the actual surface of thrusting is exposed only in the “window” of Muddy Peaks Basin. The mountain is a unit in stratigraphy, and in all parts the lower beds show the intense shattering which is a

characteristic feature in the vicinity of Muddy Peaks. Moreover, the unusual relation of older strata to younger along the entire north side of the mountain is strong evidence of the unity of the block. The known portion of the overthrust plate, therefore, ex-



FIG. 6.—Devonian limestone, at the north end of Muddy Peaks Basin. A thickness of about 600 feet is shown. Gray Jurassic sandstone beneath the overthrust appears at the left of the view.

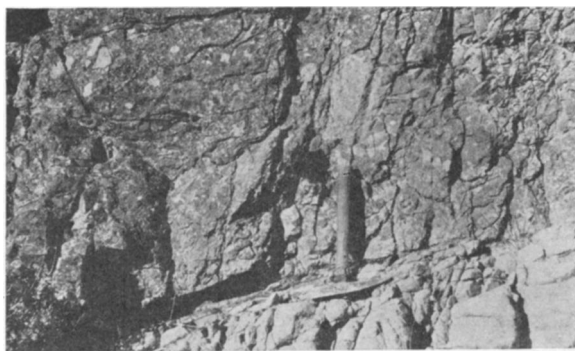


FIG. 7.—Close view of the overthrust contact. The hammer rests on the Jurassic sandstone. Well-cemented breccia lies above the surface of overthrust.

tends from the west side of the Muddy Peaks mass to Bluepoint, a distance of nearly 18 miles, and from Piute Point to the south side of White Basin, a distance of 10 miles. It is not possible to estimate the original dimensions of the plate. An indication that the movement affected a large area is given by the fact that the stratigraphic displacement apparent in Muddy Peaks Basin is ap-

proximately 9,000 feet, and yet the thrust surface is almost parallel to the bedding. The portion of the plate that formerly lay north of the Arrowhead fault has been removed by erosion, whereas on some other sides of Callville Mountain the strata involved in the movement have been carried downward by normal faulting.

Structural features adjacent to Callville Mountain.—North of Callville Mountain the Mesozoic rocks form a broad anticline with its axis extending slightly north of west. Lateral movement on the White Basin fault has caused displacement of the strata within the anticline, corresponding to the offset in the north boundary of Callville Mountain. To the east the fold plunges beneath Tertiary sediments, and to the west it dies out on meeting a stronger north-south anticline which is overturned toward the east. The north-south fold is affected by a strike fault, and near Callville Mountain the structure is further complicated by overthrusting. An overturned block of Kaibab and Moenkopi limestones has been thrust toward the northeast and now lies directly on the Jurassic sandstone. The thrust plane dips to the southwest at an angle of 60° ; but it is possible that its original attitude was less steep, and that its present inclination is in part due to tilting during normal faulting which has affected the block.

One structural feature south of Callville Mountain deserves special mention. Nearly a mile southeast of the Muddy Peaks mass an isolated block of Callville limestone forms a prominent ridge. The beds dip northwest at an angle of 30° , and on the south side the block is faulted down against Jurassic sandstone. This relation, which is similar to that on the north side of Callville Mountain, suggests that on the south side also the overthrust plate has been faulted down against younger formations. To what extent this is true cannot be definitely determined, because the Tertiary deposits conceal all except small portions of the older rocks. Possibly the isolated exposure of Callville limestone is only a local feature, with exceptional structural relations.

DIRECTION OF OVERTHRUSTING

No striations were found on the polished thrust surface to indicate direction of movement; but crumpling and minor thrusting in

the vicinity of Muddy Peaks Basin suggest that the overthrust plate moved from southwest to northeast. Further evidence favoring this conclusion is furnished by the strike of the minor overthrust north of the Arrowhead fault. Very probably this thrust was associated with the major movement, and had the same general direction. Some caution must be used, however, in drawing conclusions from the present strike of the smaller thrust plane, for it may have been changed considerably by the normal faults that cut the block.

GENERAL DEDUCTIONS

The east side of Callville Mountain is less than 40 miles from the Grand Wash Cliffs; and the original eastern edge of the overthrust plate was probably much nearer the western edge of the plateau. Thus there is evidence of intense compressive deformation near the border of the Basin Range region, closely adjacent to a wide area in which the effects of crustal compression are practically absent. Further evidence of the intensity of the post-Jurassic revolution in this part of Nevada is seen in the closely compressed and overturned fold extending north from Callville Mountain. This close folding and the overthrusting involve the same Mesozoic strata, and therefore may be different expressions of the same general crustal movement.

Rowe has reported an overthrust in the Spring Mountain Range, 40 miles west of the Muddy Mountains, stating that "the Carboniferous limestone is thrust over the red Mesozoic sandstone."¹ This description suggests the possibility that the feature is contemporaneous with the Muddy Mountain overthrust. It is a noteworthy fact that in a large part of the Spring Mountains and in neighboring ranges folding is gentle or practically absent. The writer ventures the suggestion that detailed mapping may show some of these ranges to be faulted portions of a great overthrust plate. Evidently the post-Jurassic revolution had a profound effect in at least a part of southern Nevada, and further field work may be expected to reveal additional evidence of the movement.

¹ Quoted by J. E. Spurr, *U.S. Geol. Survey Bulletin No. 208*, p. 177.